

THE EFFECTS OF FOREST FIRES
ON ARCHAEOLOGICAL SITES

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Presented at the Symposium "A Burning Issue? Effects of Fire on Archeological Resources". 49th Annual Meeting of the Society for American Archaeology, Portland. April 14, 1984.

INTRODUCTION

One of the major activities of the U.S. Forest Service since its inception in 1905 has been to protect the Forests of the United States from destruction by wild fires. To this end, an extensive, well-organized organization of people and equipment has been organized with one goal in mind - to contain, control, its extinguish forest fires as quickly as possible. This philosophy views forest fires as a danger and a threat that should not be tolerated, but fought and extinguished. For many years, the prevailing management policy was to eliminate fire from the ecological system through fire suppression activities.

Within the last two decades, however, increased attention has been paid to the role of fires in the ecosystem. With this philosophy, fire is seen as a natural phenomenon that is vital and necessary for healthy and prosperous forests. Rather than an enemy, fire is seen as a management tool that, when properly used, can reduce the dangers of uncontrolled wild fires and result in an overall improved environment. More and more, it is becoming clear that the fire suppression policies of the past have led to greater accumulations of fuel in the forests and, as a result, more intense fires than would have occurred if natural fires had not been suppressed to the extent they had been.

This change in philosophy occurred at a time when public land management agencies were being called upon to assess the impacts of their management activities on a wider range of resources than they had previously considered. One such resource was the cultural resource, and as this new attitude towards the role of fire in land management was being considered, interest developed in how it effected these other resources.

Perhaps the first study to assess the impacts of fire to archaeological sites occurred in 1972, when a lightning-caused fire burned 2,680 acres in Mesa Verde National Park (Switzer 1974). Five years later, in 1977, two large fires were studied in detail by Forest Service and National Park Service

archaeologists as a coordinated, cooperative project. These were the La Mesa Burn, on Bandelier National Monument and the Santa Fe National Forest in New Mexico, and the Radio Burn on the Coconino National Forest in Arizona. Since 1977, two other forest fires have been examined on the Coconino National Forest to evaluate fire and fire fighting effects to archaeological sites.

Other fires have also been examined in the western United States by both Park Service and Forest Service archaeologists; the results of these studies have been incorporated into federal policies and training programs related to fire; however, published reports of these studies have not yet appeared.

This symposium provides the first major opportunity to bring the results of these studies together, and is an appropriate place to summarize the archaeological studies that have been conducted at five forest fires in the Southwestern United States since 1972.

THE MOCCASIN FIRE, MESA VERDE NATIONAL PARK, 1972

As previously mentioned, this is probably the first instance of a forest fire that was studied to assess its impacts on archaeological sites. The Moccasin Fire lasted for five days and burned 1,080 acres on Moccasin Mesa in the archaeologically rich Mesa Verde National Park, and 1600 acres on tribal lands of the Ute Mountain Ute. Sites in the burn area contained pit house and pueblo sites of the Mesa Verde Anasazi and dated from Basketmaker III to early Pueblo II periods. The fire burned very hot and moved very quickly. Exposed outcrops of sandstone were fire-reddened and most brush and small trees had been reduced to a fine gray ash that was at least 4 in. deep. The vegetation of the Moccasin Mesa area before the fire was a combination of pinyon-juniper forest with dense oak brush and scrub chaparral. Only the largest trees were left standing as charred tree-trunks. A complete survey of the burn area was not made, but observations of the impacts of the fire and fire fighting activities were made in a number of areas (Switzer 1974).

THE LA MESA FIRE, BANDELIER NATIONAL MONUMENT, 1977

The largest, and most thoroughly studied forest fire project began on June 16, 1977 and lasted for seven days. Over 15,000 acres were burned on lands administered by Bandelier National Monument, the Santa Fe National Forest, and the Los Alamos Scientific Laboratory. Although the fire was encircled with a fire line, it dropped into Alamo Canyon and, whipped by shifting canyon and slope winds, burned outside its initial area of containment.

Many forested areas in the fire zone had not burned for years and large amounts of fuel in the form of branches, fallen trees, dry leaves, etc. lay on the ground. Moisture was critically low due to a dry spring and early summer, and fuels burned very quickly, fanned by winds which gusted to 40 miles per hour. The fire moved towards the city of Los Alamos, the Los Alamos Laboratories, and the residential area of Bandelier National Monument; consequently, firebreaks were built quickly to protect these areas. State Road 4, a two-lane paved highway, was expected to halt the fire as well as these firebreaks; however, it was moving with such force and intensity that it swept across the highway, forcing a fire crew to abandon their equipment.

Due to the rugged character of the country, fire crews and supplies were moved by helicopter into the more remote parts of the area. Areas were cleared of brush and trees to construct helispots to facilitate helicopter use. Airplanes were used to drop water and slurry, a chemical fire retardant, in many parts of the fire.

The fire was finally contained on June 23 after burning about one-third of Bandelier National Monument.

The La Mesa Fire is unique in that it was the first time archaeologists were deployed with fire fighters to help avoid damage to archaeological sites. About 30 archeologists worked to guide bulldozers around sites, survey potential fire control lines, and otherwise identify sites that might have been damaged by fire fighting activities. After the fire, archaeologists also monitored various clean-up activities.

As might be expected, the introduction of something completely new and different in the midst of a tense fire fighting situation caused some initial grumblings from the fire fighting crews, but no outright hostilities developed that we are aware of. Archaeologists were able to help the fire fighters by guiding them into areas, providing them with maps, and, in some cases, comic relief in what are often strained working conditions.

When the fire was over, the National Park Service conducted several detailed studies of the effects of the fire on archaeological sites. This work included a survey of all fire lines within Bandelier National Monument and excavation of selected sites burned in varying degrees to obtain information on the specific effects of fire on artifacts, architecture, and ecofacts and to salvage any sites that were severely damaged during fire suppression activities.

Approximately 10 miles of firelines were constructed with bulldozers, and about 13 miles of line were dug by hand. Survey crews walked along these lines, intensively surveying a swath about 125 ft. wide. Four helispots and a 2 acre safety zone were also surveyed. Within these approximate 400 acres that were surveyed, 100 sites were recorded. This is a site density of 180 sites per square mile. **DOUBLE CHECK ACRES SURVEYED AND SITE DENSITY WITH BRUCE** About half were one-to-five room masonry structures, seven were 10-to-50 room pueblos, seven were multi-unit large pueblos, three were Archaic and Basketmaker lithic scatters, and the remainder were five-to-ten room pueblos. Tuff, a fairly light, easily worked, volcanic stone was used to construct most of the masonry structures. The majority of sites dated between A.D. 1200 to 1500.

The environment of the area consists of broad, gullied mesas cut by steep canyons. Elevations ranged from 6500 to 9600 ft. and vegetation was predominantly (75%) ponderosa pine forest with some areas of spruce, fir, and aspen. About 25% of the area was in pinyon-juniper forest.

Following the survey, three sites were excavated, all one-to-two room structures and were selected to examine the extremes of fire damage: two were highly charred and one was only moderately burned. Excavations were conducted in three arbitrary levels that were selected to assess the depth to which heat from the fire may have penetrated and potentially effected

highly burned loose surface material, a 10 cm. thick layer below this, and a 20 cm. thick layer that extended to the floor of the structures. Various samples were taken from the surface and from the excavations for thermoluminescent, tree-ring, pollen, flotation, soil, faunal, archaeomagnetic, Carbon-14, and obsidian hydration analyses.

THE RADIO FIRE, COCONINO NATIONAL FOREST, 1977

The day after the La Mesa Fire began, a runaway juvenile left a campfire untended in the Coconino National Forest near Flagstaff, Arizona. This campfire spread and over the next three days burned 4,600 acres. The fire began at the mouth of a canyon on the south side of Mt. Elden, a 2,000 ft. high dome that is part of the San Francisco Peaks. Wind and extremely dry conditions proved as devastating for the Radio Fire as they had for the La Mesa Fire. The fire swept rapidly up the canyon and destroyed a number of radio transmitting facilities on top of Mt. Elden. Luckily, Forest Service radio communications facilities, also located atop Mt. Elden, were not destroyed. Within minutes, the fire had spread over the top of the mountain and was moving northeast towards the fire look-out tower. The fire look-out had three minutes to vacate the tower before it and all his possessions in the look-out tower were engulfed by the flames. After having burned the entire top of the mountain, the fire moved down the eastern slopes, a potential threat to numerous homes at the base of the mountain. Homes below the southeast side were not burned, however, several homes in more isolated settings to the northeast were damaged by the fire despite the efforts of owners, county, and Forest fire-fighters.

Besides the threat to private property, there were major fears that if the fire was not controlled, it might spread to the San Francisco Peaks themselves. Consequently, considerable energy was expended in building fire control lines and dropping water and slurry in critical locations to protect homes, radio facilities, and to prevent the fire expanding onto the San Francisco Peaks. In this regard, the winds cooperated and blew the fire to the northeast until it was finally contained within a series of control lines and U.S. Highway 89.

Unlike the La Mesa Fire, no archaeologists were involved in the fire fighting activities. Fortunately, many of the fire-fighters had received archaeological training as part of the Forest's Para-archaeology training program and purposely guided bulldozers around archeological sites during fire control line construction.

Following the fire, plans were made to salvage the burned timber from the area and to remove dead trees to avoid the insect infestation that rapidly follows such destructive, killing fires. From previous archaeological work in this area, it was known that the area had numerous archaeological sites, and a program of intensive archaeological survey of the entire burned area was begun so that sites could be avoided by the imminent logging activities.

National Park Service and Coconino National Forest archaeologists had been in communication with each other while both the Radio and La Mesa Fires were burning, and it was agreed to coordinate the archaeological studies both agencies were about to begin on these two major fires. Throughout 1977 and

data and information resulting from fire-related archaeological studies have been shared by the two agencies.

During the Radio Fire, about 12 miles of firelines were constructed by bulldozers and **FIND OUT MILES OF HAND LINE** miles were dug by hand to contain the fire. In all, the Radio Fire cost \$1,136,096 to combat. Costs of rehabilitation, resource damage, archaeological, and other resource studies conducted following the fire have not been assembled.

Archaeological crews surveyed not only the fire control lines, as was done on the La Mesa Fire, but the entire burned area of 4,594 acres. A total of 165 sites were recorded, resulting in a site density of 23 sites per square mile. Sites are mostly pit house villages, ranging from one to ten structures per site, and one-to-three room masonry pueblos. A few larger pueblos, sherd scatters, and one historic site were also recorded. Most pit houses were simply depressions in the ground, although some were outlined with dacite rocks and boulders. Pueblos were also constructed of dacite and occasional basalt rocks. Dacite is similar to granite, although it is more susceptible to crumbling and weathering than is granite. All prehistoric sites can be assigned to the Rio de Flag, Angell-Winona, Padre, and Elden phases of the Northern Sinagua, and date between about A.D. 900 and 1200. The one historic site was a small ranch used in the 1920's.

The environmental situation of the Radio Fire contains a diverse assemblage ranging from ponderosa pine and fir forest on top of Mt. Elden, open chaparral and chaparral/ponderosa mixed zones of cliff rose and scrub oak, pinyon-juniper-oak concentrations, and open ponderosa pine forest. Archaeological sites were only found below Mt. Elden, in areas of ponderosa, ponderosa-chaparral, and pinyon-juniper.

Upon completion of the survey, in 1978, four sites were excavated to better evaluate the impacts of the fire and to provide comparative information with the La Mesa Fire. Two sites were one-room masonry field houses, one only lightly burned and the other moderately burned and cut by a bulldozer line. The other two sites were larger one-room, masonry-outlined pit houses. As before, one was only slightly burned and the other was severely burned. Excavations were conducted in several levels, corresponding to the densely burned surface level, and then levels 10 to 20 cm. deep until the floors of the structures were encountered. Test excavations were also made outside the structures. Samples were taken for pollen, flotation, tree-ring, and obsidian hydration analyses, but these have not been analyzed. Besides samples of sherds and obsidian collected during these excavations, several sites had been collected prior to the fire and should prove interesting control examples.

THE JACKET FIRE, COCONINO NATIONAL FOREST, 1977

Another fire was burning on the Coconino at the same time as the Radio and La Mesa Fires. The Jacket Fire was caused by a lightning strike and was located 17 miles east-southeast of Flagstaff and the Radio Fire. It lasted three days and burned a total of 290 acres. Not as much effort went into fighting the Jacket Fire as the other two mentioned since it was located in an unpopulated area of the pinyon-juniper forest. Pinyon-juniper areas are not

not have high commercial timber values. Many parts of the pinyon-juniper forest belt are designated as prescribed fire management zones where natural fires are allowed to burn unchecked, providing there is no threat to life or property. However, during severe fire seasons, such as the summer of 1977, greater efforts are made to control fires in the pinyon-juniper to avoid potential large scale, project, fires.

The Jacket Fire was contained by a series of fire control lines dug by both bulldozer and by hand. Since it was located in a different part of the Forest and in a different environmental zone, a portion of it was selected for archaeological inspection to provide comparisons with the archaeological work done for the Radio Fire.

Although only 64 acres were intensively surveyed, 12 sites were recorded for a site density of 120 sites per square mile. Had a larger area been surveyed, site density would probably have dropped to the 50 to 60 sites per square mile that is more typical of this area. Eight sites are one-to-three room limestone masonry pueblos and the remaining four sites are sherd and lithic scatters, probably representing hunting and gathering activities. All sites date to the A.D. 1066 to 1130 period of the Northern Sinagua.

THE WALLACE FIRE, COCONINO NATIONAL FOREST, 1979

The last fire that will be discussed also occurred on the Coconino National Forest in July of 1979. **WAS THIS NATURAL OR MAN-CAUSED? HOW MANY MILES OF CAT AND HAND CONTROL LINES WERE BUILT?** The Wallace Fire began at Wallace Tank, about 22 miles northwest of Flagstaff, and lasted for three days. Prevailing southwesterly winds whipped the flames to very hot temperatures and pushed them across fire control lines and U.S. Highway 180 which had been expected to stop the spread of the fire. Both bulldozers and hand dug fire control lines were constructed to contain the fire, but not before 645 acres had been burned.

Archaeologists were not present during fire suppression although, as in the case of the Radio Fire, several fire-fighters had received previous training in the Forest's para-archaeologist program.

This particular part of the Forest was known to have a site density of about 20 sites per square mile and, since several sites were located by the fire-fighters during suppression activities, complete archaeological surveys were conducted following the fire as part of salvage timber sale preparations. Surveys began two weeks after the fire was under control and located 14 archaeological sites. Ten were one-to-three room pueblos of basalt masonry, two were pit house sites, and two were sherd and lithic scatters. All are affiliated with the Cohonina cultural tradition and date between about A.D. 950 and 1066.

The environment of the Wallace Fire area consists of dense thickets of young ponderosa pine trees only a few inches in diameter. Thickets of this sort, particularly when weather conditions have been dry, are extremely flammable and burn quite hot. With these conditions present in 1979, the Wallace Fire spread rapidly and destroyed almost all of the young trees in this burned area.

SUMMARY OF FIRE AND ARCHAEOLOGY CASE SITUATIONS

These five forest fire studies include three states, two agencies, and 296 archaeological sites. Although basic information was recorded in all studies, none are completely comparable. The Moccasin Mesa fire only involved cursory inspection of the fire area; the La Mesa Fire survey only examined fire control lines and other construction areas; the analyses of the Radio Fire excavations are not available; and only a portion of the Jacket Fire was surveyed.

Despite these inconsistencies, a good body of information exists with which to examine the impacts of fire on archaeological sites. In examining the results of these five studies, certain similarities are evident and are common to all studies. In other instances, certain results are unique to an individual study area.

These results will now be discussed.

THE IMPACTS OF FIRE SUPPRESSION ACTIVITIES ON ARCHAEOLOGICAL SITES

All studies have found that, while fire does effect archaeological sites, the greatest impact occurs from fire suppression activities, particularly when heavy equipment is used.

The use of fire breaks is the main method by which fires are fought. Efforts are made to encircle a fire with lines that have been cleared to bare soil by bulldozers or by scraping and shoveling by hand labor. Existing roads and highways are used for this purpose as well. If conditions are right, the fire will stop at these lines since all combustible materials have been removed. The location of firelines is subject to numerous considerations, such as wind and weather conditions, quantity of fuels on the ground, slope conditions, and predictions as to the direction and intensity the fire will move. Bulldozers are usually used in flat terrain or areas of dense vegetation, while hand labor is used on slopes or in areas where burnable fuels are low. Once the fire is contained within these fuel breaks and there is no danger of it spreading outside these control lines, the fire is considered to be under control.

Following the fire, these lines are rehabilitated so they do not contribute to the increased erosion that generally follows a fire due to the area being denuded of vegetation. Rehabilitation is done by pushing soil and debris back into the fire line to recontour the surface of the ground. Furrows and mounds of earth are also constructed across the lines to reduce soil and water erosion. Seeds are usually sown along the fire lines as part of this rehabilitation.

Damage to sites by heavy equipment used during suppression activities was found to have the most severe impact to archaeological sites. Bulldozer blades range from six to 12 ft. in width, will often cut as deep as a foot, and virtually everything in their path will be removed during fireline construction. Displacement of artifacts and destruction of architecture was the main effect noted. Damage can also be severe where bulldozers turn

be braked motionless, while power is applied to the other track to "twist" the bulldozer around. Such turning leaves deep gouges in the earth which, should a site be present, can severely disturb a site.

In the La Mesa Fire, only two sites were impacted during initial fire line construction using bulldozers. However, during later widening of the lines and when the lines were bladed flat with bulldozers, 15 sites were severely damaged due to poor communications, and archaeologists were not present. Eight of these sites were completely destroyed, and seven had major portions of their architecture removed. Other portions of sites were buried beneath piles of brush and dirt. For the three fires inspected on the Coconino National Forest, 6 to 25 percent (average 16 percent) of all sites in the fire area were damaged to some degree during bulldozer fire line construction. These figures would undoubtedly be higher had Forest Service personnel not been attempting to steer bulldozers around archaeological sites. On the Radio Fire, ten sites were impacted by the 12 miles of bulldozer line that were constructed. Three sites were damaged on the Wallace Fire, and 3 sites in the Jacket Fire.

DAMAGE TO SITES BY HAND LINE CONSTRUCTION

Information on damage caused by hand line construction is only available for the La Mesa Fire, where 13 miles of handline were constructed. Handlines caused very little disruption and it was evident that even crews intentionally avoided sites during line construction. Displacement of artifacts and exposure of subsurface trash was the most common form of disturbance noted for handline construction. Such displacements were usually restricted to a short distance from the site. Hand clearing of trees and brush occasionally resulted in vegetation falling onto sites, partially obscuring them. This would not normally cause problems, unless a site had standing walls. Although placing such slash on a site increases the possibility of its incurring fire damage from future fires.

DAMAGE TO SITES BY INCREASED PEOPLE IN AN AREA

One impact is commonly found whenever numbers of people are in an area of archaeological sites - the casual collecting and stockpiling of artifacts. In the La Mesa, Radio, Wallace, and Jacket fire, instances were commonly found where firefighters collected artifacts and left them in little stacks at various places on the site. During the La Mesa Fire, many firefighters were left on a large site for some time before they were moved to other locations. During this time, considerable pocketing of artifacts occurred until one of the archaeologists gave an impromptu interpretive talk about the site and archaeology. It was noted that many small piles of artifacts later appeared around this ruin. The high visibility of archaeologists during the La Mesa Fire and their close interaction with firefighters undoubtedly helped to minimize such casual collecting. Collecting of artifacts, particularly projectile points, is a major impact resulting from the increased numbers of people brought into an area because of a fire.

DAMAGE FROM FIRE RETARDANTS

During the fire, water and slurry, a red-tinted chemical fire retardant, is dropped onto a fire by helicopter and aircraft. In severe areas, or in situations, such as on the Radio Fire, numerous loads of slurry will be dropped in order to protect property or to halt the advance of the fire. In such places, the entire area is stained pink. This stain washes away after several rainfalls and causes no harmful effects, other than the temporary creation of new and exotic pottery types such as Slurry Red-on-brown.

MOP-UP ACTIVITIES

Mop-up crews are brought into an area after the firelines are constructed to improve them to ensure fire does not spread across them onto unburned areas. They extinguish as much of the fire as they can between the fireline and the major burn. Burning trees are cut down so sparks do not spread to cause additional fires. As the area along the fire lines is secured, the crews move further into the burn to extinguish spot fires, burning branches, and any other hot spots to prevent flare-ups from occurring. Such mop-up work may continue for weeks after the fire is officially controlled, since tree roots and stumps will often continue to burn underground, flaring up into new fires from time to time. In order to prohibit this sort of flare-up, burning roots are dug out and smoldering logs are cut into small pieces.

When trees are growing in archeological sites, mop-up operations can impact them in much the same way as pothunting. Irregular holes may be dug into sites in an effort to extricate smoldering roots. Three sites were damaged in this manner in the La Mesa Fire and in at least one site on the Radio Fire, mop-up activity was used as an excuse to dig extra holes into an archaeological site.

IMPACTS BY FIRE ON ARCHAEOLOGICAL SITES

While fire suppression activities have the greatest impacts on archaeological sites, fire itself can cause effect archaeological remains. In forested situations, it can be assumed that most sites have been burned over at least once since their abandonment. The degree of effect caused by such burning depends upon several factors - the intensity of heat, its duration, the amount of fuels on a site, and the penetration of heat into the soil. While forest fires are controlled by many factors, such as wind, humidity, topography, vegetation type, and the amount of combustible material on a site, the latter is probably the most important determinant of fire intensity. Grass fires, for example, have less combustible material and burn more quickly than in a densely wooded area. Fuel loads, the amount of combustible material in an area, vary considerably from area to area and, as a rule, the temperature of the fire increases in proportion to the fuel load. In the Northwest and in California, fuel loads may be as much as 200 tons per acre and will generate surface temperatures of 1093 degrees Celsius (Countryman 1964). On the La Mesa Fire, fuel loads ranged between 5 and 20 tons per acre. On the Radio Fire, fuel loads ranged from 4.8 tons per acre along the base of Mt. Elden to 0.5 tons per acre in the lightly forested areas. Of interest is the fact that the hottest and most severe burning

Elden. Intensity of burning was less in the flatter areas where fuel loading was less. The higher fuel loads were in areas of dense chapparal, which tend to burn hotter than areas where ponderosa pine branches and needles form the bulk of fuel loads. **GET SOME FIGURES ON COCONINO FUEL LOADS, PARTICULARLY FOR RADIO, WALLACE, AND JACKET FIRES**

Damage to archaeological materials begins when temperatures approach 300 degrees Celsius. This is the temperature at which ponderosa pine begins to be killed. Higher temperatures will occur in chapparal situations, particularly when combined with the high winds that often accompany large scale forest fires. Temperatures as high as 1500 degrees Celsius may occur in areas where pitchy roots burn. In most fires, the intensity of burning is highly variable. A fire may jump certain areas, leaving them undisturbed, while in other areas all vegetation may be completely reduced to ash and the underlying soil sterilized due to intense heat.

In the fires studied to date, about 90 percent of all sites in a forest fire area were burned to some degree and the intensity of burning seems directly related to the amount of fuels on and around the sites.

Obviously, historic period sites containing wood, or consisting of wooden structures, can be completely destroyed by a fire. In the Radio Burn, for example, all wooden evidence for a 1920's ranch was completely burned away, leaving only metal pieces and rock foundations as evidence for the site. On the La Mesa Fire, a log cabin was also completely burned away, leaving only the imprints of the logs with nails still in situ in the ground.

Fire will burn pot sherds, change their colors, and alter paints and glazes, making identification difficult in some cases. A common effect noted on fires on the Coconino National Forest is the oxidizing as well as carbonizing of sherds. This is of major concern with plainware pottery where tempering materials are obscured or so altered by heat that they can no longer be identified. Such changes begin to occur with temperatures of 500 degrees C. (925 degrees F.). In pine areas, a glaze-like deposit, probably resulting from pine pitch, often coats the exposed surfaces of sherds. In most cases, however, particularly after a few rains or when sherds were washed in the laboratory, type identifications could be made. Culinary sherds, which are usually more coarsely tempered, are sometimes more severely effected by being made more friable than is normally the case.

With temperatures over 300 degrees C. (590 degrees F.), stone artifacts will spall, crack, or break from intense heat, the amount of damage being dependent upon the type of stone involved. On the La Mesa Fire, where tuff was the major construction material in sites, nearly half of the masonry pueblo sites exhibited spalling or cracking of building stones. Tuff also became increasingly friable and, in some sites, stones were almost reduced to powder. In other cases, the tuff was altered to such a degree that building stones became much more susceptible to erosion. On the Radio, Wallace, and Jacket Fires, where building stones were of dacite, limestone, or basalt, impacts were not as great. This can be seen on a collection of manos from one site on the Jacket Fire where sandstone manos were severely cracked but basalt manos were only fire blackened. It appears that the more intense a fire, the more friable stones will become and the weathering process will be correspondingly accelerated.

Rock art sites, particularly pictographs, where designs are painted onto stone, are especially susceptible to damage by fire. Designs can be scorched or completely burned away, while petroglyphs on friable stone, such as sandstone or limestone, can spall off. No rock art sites were identified on any of the fires studied, but this should be a concern in areas where rock art sites are numerous.

Stone used for flaked stone tools, such as chert, basalt, and obsidian, appears to be more resistant than the types of stone just mentioned. On the Radio Fire, cherts were burned grey to black in color but were seldom cracked or spalled. In addition, a dull, dark patina often formed on obsidian, basalt, and chert artifacts, particularly on the sides of the artifacts directly exposed to the fire. This patina may be a carbon residue or perhaps a result from heating the materials. Wear patterns could still be distinguished through these residues, however. In areas of intense heat, some obsidian artifacts became partially vitrified. Quarry sites can be severely impacted by fire. In the area of the Wallace Fire, several obsidian sources are known and the ability to easily distinguish legitimate quarry locations from thermal fracturing was made quite difficult by the fire. Similar problems have also been noted at obsidian quarry locations in California.

EROSION OF SITES DUE TO FOREST FIRES

Increased soil erosion following a forest fire is of major concern to land managers as well as archaeologists and a significant part of funds spent on forest fires is allocated towards revegetating a burned area. Until vegetation is re-established, sites as well as soil, can be severely eroded in the aftermath of a forest fire. Increased erosion following a fire is partly due to the loss of organic material which acts as a mulch to absorb moisture. Volatile organic materials released by high soil temperatures condense on the cooler soil layers just below the surface, forming an impenetrable layer. Consequently, instead of rain soaking onto the ground, water runs off, carrying soil with it. (Ahlgren and Ahlgren 1960; Fenn *et al.* 1976). Severe flash flooding was evident for several months after the Radio and La Mesa Fires. In the case of the Radio Fire, virtually the entire side of Mt. Elden was denuded by fire, causing record run-offs from this watershed which cut gullies as deep as 10 ft. during the summer following the burn.

The increased fragility of soils, combined with the great number of dead and standing trees, also results in large numbers of trees and stumps to become uprooted following a fire. When growing inside of structures or within sites, damage can occur as trees become blown down. Damage of this sort was noted at several sites in both the La Mesa, Radio, and Wallace Fires. Two sites in the La Mesa Fire (2 percent) and two sites in the Wallace Fire (11 percent) were noted with this sort of damage. Such damage will increase over the years as more trees are uprooted and it is sometimes difficult to determine whether a mound of rocks is a highly eroded site or simply a mound of rocks left from an uprooted tree.

SUBSURFACE EFFECTS ON ARCHAEOLOGICAL REMAINS

A major concern of all fire studies has been the potential effects of fires to archaeological materials below the surface of the ground. This question was the main reason for the site excavations conducted as part of the studies of both the La Mesa and the Radio Fires.

In both studies, identical results were found. Altering of artifacts, construction stone, and other materials was limited to the first few centimeters below the ground. Below 5 cm., there was no visible change in soil or cultural materials.

An exception to this is where stumps and roots burned beneath the ground. In these instances, soil was baked red and hard, giving the appearance of prehistorically plastered floors and walls. At one site excavated on the Radio Fire, it was impossible to determine whether a structure had storage pits or whether these were the constructs of burned roots. Considerable difficulty also resulted when trying to trace out roof and floor levels.

Although there was no visual effect to materials below 5 cm., the La Mesa Fire study addressed the potential heat transmission below the surface and its potential for altering the results of heat-sensitive dating techniques such as archaeomagnetism. Their study pointed out that most research on forest fires and soil temperatures indicates that soil is a poor conductor of heat and that heat is rarely sustained for a long enough period of time to significantly raise subsurface temperatures (De Bano and Rice 1970; Fenn et al 1976; Heyward 1938). Even when intense temperatures are recorded on the surface of the ground, it drops off rapidly within the first several inches. The depth of heat penetration is also related to soil moisture and soil type. Soils high in clay or organic content are more resistant than sandy soils which transmit and retain heat more readily. Studies of the La Mesa Fire suggest the most intense surface heat did not last longer than 15 minutes and even in the most severely burned areas, soil temperatures were less than 100 degrees Celsius within the top 2 inches of the surface.

Several consultants examined materials from both the surface and the excavated levels of the sites excavated during the La Mesa Fire and found some specific effects that resulted from the heat of the forest fire. Thermoluminescent values were measured for both pottery sherds and basalt and found that surface sherds registered dates 24 percent too low of the expected age based upon ceramics found on the sites. However, even this was found to be variable. One sherd from the surface of the site, where temperatures were highest, gave a result within the 5 percent accepted margin of error, while a sherd from within 5 cm. of the surface produced a date too low of its expected age. At a site that was less severely burned, a value that was reduced by only 10 percent of its expected age was obtained.

Obsidian hydration values were also found to be altered by the fire. Only 35 percent of 110 edges had measureable rinds from a site that was severely burned, while 70 percent of 138 edges from a site that had not been burned had measureable rinds.

Ethnobotanical remains were unaffected by the fire in that they could still be separated from burned contamination. Archaeological charcoal was thoroughly carbonized and more friable than charcoal resulting from the La Mesa Fire which was hardened and varied in its degree of combustion.

Prehistoric pollen samples were also unaffected, although surface samples appear to have been completely burned away. Pollen grains are destroyed at temperatures greater than 300 degrees Celsius and, since none of the pollen grains collected from the surface of a severely burned site were burned, they were apparently deposited after the fire. Pollen samples collected from below the ground were not effected by the fire and, though several did not contain very well-preserved pollen, other samples provided adequate counts for analysis.

From the La Mesa Fire study, only two poorly preserved tree-ring samples were recovered from the excavations. Though neither was datable, they were judged unaffected by the fire.

ENHANCED SITE VISIBILITY

During the Moccasin Fire, a positive benefit for archaeological sites was noted as a result of the fire. Because of the removal of dense underbrush, numerous archaeological sites could be seen that had been obscured by vegetation before the burn. The discovery of numerous prehistoric check dams and terraces was a direct result of the clearing caused by the fire.

In the Radio Fire, the removal of duff that had previously covered the forest floor enhanced the ability to observe sherd and lithic scatters that could easily have been missed, as well as the distribution of artifact clusters on several sites.

However, this enhanced visibility is not always the case. Recent follow-up surveys of the Wallace Fire recorded an additional five sites that had not been reported by the original survey, increasing the number of sites in the area by a substantial 26 percent. While some of these may have just simply been missed by the first survey, four of the sites were areas of scattered artifacts or low-lying jacal wall outlines that were probably completely covered by the ash following the fire. Other fires inspected on the Coconino National Forest were surveyed after rains had fallen and washed away some of the ash. The Wallace Fire, on the other hand, was surveyed almost immediately after the burn when considerable ash still covered the ground.

As a result of numerous post-fire timber sales and activities in the Radio Fire area, archaeological crews entered the area many times to relocate and mark sites for avoidance from project activities. During the course of these visits, eight additional sites were found, for an increase of 5 percent over the number first reported. In examining the distribution and nature of these sites, it is apparent that they were not missed because they were covered by ash, since most are one to two room masonry structures identical to the majority of sites found on the original survey. What is evident is that these sites tended to occur on the sides of roads that were used to divide the project into survey units. It would appear that these sites were missed because they occurred at the start and end of survey transects, when the surveyors were preoccupied with determining their compass bearing route of travel or lessened their attention to watching for sites because they had finished their transect.

In another area in the same vicinity as the Radio Fire, multiple surveys were

not been recorded by the original survey. In this instance, 7 percent of all sites in the area were found during the resurveys.

These two examples suggest that a "100 percent" survey in the Flagstaff area will routinely miss about 5 to 7 percent of the sites in an area. Applying this figure to the results of the Wallace Fire indicates that perhaps 20 percent of the sites in a forest fire will be obscured by ash until it is washed away.

FOLLOW-UP ACTIVITIES

Both the Radio and La Mesa Fires point out the importance of communication and continued surveillance of a burned area following a forest fire. During construction and rehabilitation of the fire controls lines in the La Mesa Fire, 15 sites were damaged because some bulldozer operators had not been told to avoid areas marked with red flagging tape. During subsequent logging activities after the Radio Fire, seven sites were damaged by logging activities for similar reasons. In both fires, lack of understanding on the part of archaeologists as to the full range of activities involved during and after a fire contributed to the destruction of archaeological sites. A misperception on the part of fire-fighters that the job of the archaeologists was completed, once the fire was controlled, also contributed to site destruction. Communication throughout all parts of a fire and follow-up activities is mandatory to ensure sites are not inadvertently destroyed.

RECOMMENDATIONS

These fire studies have indicated the importance of having archaeologists present when fires occur in areas of high archaeological sensitivity. This is particularly important when heavy equipment is used, since this was found to be the most damaging aspect of fire suppression activities. Despite the reluctance of some traditional fire-fighters to have a new and different element added to the fire organization, the La Mesa Fire indicates archaeologists can work in line situations with fire-fighters and not interfere with fire suppression activities.

Increased training of fire personnel in recognition of archaeological sites and the need to protect them during all stages of project work would do a great deal towards ensuring the protection of sites from both heavy equipment as well as less damaging activities such as casual collecting of artifacts during mop-up operations. The training given to Forest personnel as part of the para-archaeology program was a direct factor that led to the protection of sites during fire line construction.

Archaeologists also need training and experience on fires so they better understand fire suppression activities and the fire organization. Incorporation of archaeologists into the Plans Section of the fire organization would also be useful so that the Fire Boss can be advised of areas and activities needing archaeological monitoring.

Bulldozer operators and line scouts should be briefed on the necessity of watching for and avoiding archaeological sites. In particular, they should

know what color of flagging tape is being used to indicate archaeological sites.

It would be useful to standardize a certain color, combination, or design of flagging tape that would only be used to indicate archaeological sites. Agencies should consider developing a standardized, unique flagging code to designate archaeological sites in all project situations, not only during fire suppression. This would ensure higher recognition in fire-fighting personnel of that agency of the presence of archaeological sites that need protection.

If archaeological input can be made as a regular part of fire-fighting activities, the majority of impacts to archaeological sites can be avoided. Negative effects caused by fire itself can be reduced by the removal of high fuel loads from areas of high archaeological sensitivity. As the importance of fire as a natural part of the ecosystem is recognized, this should become a more common practice. Land managing agencies are in the process of shifting their fire management policies to include more frequent, controlled burning of areas to reduce fuel loads. Such prescribed burns occur under specified conditions that result in lower temperatures and less damage than during a forest fire situation. Besides prescribed burning, other forest management practices that are primarily oriented towards improving the condition of the forest, such as thinning dense thickets, also improve conditions for archaeological sites.

During a project size forest fire, the prime considerations are for the safety of life and property and the suppression of the fire. Under such tense and frantic conditions, it is impossible to completely protect all archaeological sites in an area. However, through closer involvement and cooperation between fire-fighters and archaeologists, impacts to archaeological sites can be minimized to the point where they cease to be "a burning issue".